Tectonic evolution of east-dipping subduction zone in Caribbean

Late Cretaceous plume-induced subduction initiation along the southern margin of the Caribbean: Insights from numerical modeling

S. V. Sobolev and M. Baes, Institute of Geosciences, Potsdam University and GFZ Potsdam

In Short

- Numerical modeling of plume-induced subduction initiation
- Investigation of factors controlling the formation of one-sided subduction zone
- Explore the effect of plate motion on plumelithosphere interaction

Subduction initiation has been remained as one of the unclear issues in geosciences. Several scenarios have been proposed so far to explore this process. In a recently proposed scenario that is independent of any pre-existing weakness zone, plumelithosphere interaction plays a key role in formation of new subduction zones [1-3]. [2] showed that the arrival of a buoyant plume beneath oceanic lithosphere leads to the formation of several slabs around a newly formed plateau. In this study we claimed that plume-induced subduction initiation triggered Plate tectonics and demonstrated that in the hotter early Earth plume-lithosphere interaction led to subduction initiation only if the oceanic plate was old. Arrival of plume beneath a young lithosphere produced episodic lithospheric drips in the early Earth. In study [4] it was for the first time that the authors found evidence for mantle plume-induced subduction initiation in Caribbean region. They showed that at about 100 - 95 Ma the arrival of a large plume head, which formed Caribbean Large Igneous Province (CLIP), induced a new subduction zone in this region. They proposed that existing of 140 - 110 Ma plateau adjacent to an oceanic lithosphere created a favorable condition for subduction initiation upon arrival of mantle plume beneath the oceanic lithosphere and formation of a younger plateau at 100 Ma. They indicated that the main difference between their SW Caribbean plume-induced subduction initiation model from numerical models (e.g, [3]) is that in their model subduction initiates only on one side of the plume, not symmetrically all around the CLIP. They also claimed that this difference is because of subduction beneath the NE margin, which existed already some tens of million years before subduction initiation in the SW Caribbean (Figure 1).



Figure 1: Schematic tectonic evolution of subduction zones in Carribbean between 70-110 Ma (from [4])

In this project, we aim to investigate subduction initiation in the SW Caribbean at 100-95 Ma, using numerical models. Previous modeling studies (e.g., [2]) show that plume-lithosphere interaction can result in initiation of several subduction zones around the newly formed plateau. The question here is "why did subduction initiate only on one side of Caribbean plateau?". In our recent paper (Baes et al., 2020) whose computations were done on HLRN in the frame work of the current project we investigated factors controlling the number and shape of retreating slabs formed by plume-lithosphere interaction. Using 3-D thermo-mechanical models we have shown that the deformation regime, which defines formation of single- or multi-slab subduction depends on several parameters such as age of oceanic lithosphere, thickness of the crust and large-scale lithospheric extension rate([5]). On present-day Earth, plume-lithosphere interaction can result in formation of multi-slab subduction when the oceanic lithosphere is young (with the age of more than 10 Myr and less than 40 Myr). Single-slab subduction is facilitated by older lithosphere and large-scale extension. On early Earth, plume-lithosphere interaction could have resulted in either multi-slab suction



Figure 2: Fig. 2: Initial model set-up. The upper panel shows initial temperature field (color bar is shown at the top of figure) and the lower panel illustrates the composition of different layers of model. Different colors stand for different layers in the model, as indicated in the bottom of figure.

zones or episodic short-lived circular subductions. The former develops when the lithosphere is older than 50 Myr and the latter forms if the lithosphere is younger. We also studied the influence of plumeplateau interaction. Our model results indicate that depending on the age of oceanic lithosphere and location of plume head with respect to the plateau border, four different geodynamic regimes can be achieved: (a) oceanic trench formation, (b) circular oceanic-plateau trench formation, (c) plateau trench formation and (d) no trench formation ([6]). Our results suggest that subduction along the western margin of the Caribbean could be the consequence of plume-plateau interaction if the plume head impinged the oceanic lithosphere at a distance close to the plateau border.

Following our previous works in which the motion of plates due to plate tectonics was ignored, we plan to explore the effect of plate motion on mantle plumelithosphere interaction. Our model is consisted of an oceanic lithosphere, asthenosphere and a spherical plume (Figure 2). The model geometry is 1302 km *328 km*1302 km with total node and marker numbers of 22956285 and 378556128, respectively. Preliminary results show that plume head cannot penetrate the lithosphere and it spreads beneath the lithosphere (Figure 3a). Results of a model similar to the reference model but with stationary plate indicate comparable results except that here the plume underplating is symmetric (Figure 3b) while in the reference model plume spreads asymmetrically below the lithosphere; it propagates beneath the oceanic plate in the direct of plate motion.



Figure 3: Preliminary results of (a) a model with moving oceanic lithosphere, (b) a model with stationary oceanic lithosphere. The upper and lower panels show temperature field of lithosphere (color bar is shown at the top of figure) and compositional field of a cross-section cutting through the middle of model, respectively. The color code of compositional field is illustrated at the bottom of figure.

www

More Information

- K. Ueda, T. Gerya, S. V. Sobolev, *Physics of the Earth and Planetary Interiors* **171**, 296-312 (2008).
- [2] T. Gerya, R. J. Stern, M. Baes, S. V. Sobolev, S. A. Whattam, *Nature* 527, 221-225 (2015).
- [3] M. Baes, T. Gerya, S. V. Sobolev, *Earth Planet. Sci. Lett.* **453**, 193-203 (2016).
- [4] S. A. Whattam, R. J. Stern, Gondwana Research 27, 38-63 (2015).
- [5] M. Baes, S. V., Sobolev, T. Gerya, S. Brune, Geochemistry, Geophysics, Geosystems 21, https://doi.org/10.1029/2019GC008663 (2020).
- [6] M. Baes, S. V., Sobolev, T. Gerya, S. Brune, accepted for publication in Geochemistry, Geophysics, Geosystems, (2020).

Project Partners

T. Gerya, Department of Earth Sciences, Institute of Geophysics, ETH, Zureich